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Investigation of changes in surface properties of bituminous coal during natural weathering processes by XPS and SEM

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ABSTRACT

In this investigation, XPS and SEM were used to indicate the changes in surface properties of bituminous coal during natural weathering processes. Natural weathering processes of bituminous coal were conducted on the roof. XPS results showed that the content of C—C and C—H groups on bituminous coal surface decreased but the content of C—O, C═O, and O═C—O groups increased after natural weathering processes. Meanwhile, the contents of Al and Si elements on bituminous coal surface were also increased. SEM results showed that the surface roughness of bituminous coal was increased after natural weathering processes. Natural weathering processes not only changed surface chemical composition of bituminous coal but also changed surface topography of bituminous coal. In addition, natural weathering processes made bituminous coal surface more hydrophilic.

1. Introduction

Coal is a solid combustible material which is made up of organic and inorganic materials. Bituminous coal has the best hydrophobic property. Base on this hydrophobic property, bituminous coal is easy to float without or with only a little oily collectors. However, oxidation processes always break this natural hydrophobicity of bituminous coal. Coal oxidation processes are divided into two primary types, natural weathering processes and laboratory oxidation processes. Natural weathering processes and low temperature oxidation processes are usually considered to be more realistic coal oxidation [1].

Coal surface properties will be changed after natural weathering processes. For example, natural weathering processes can increase the content of oxygen containing functional groups on coal surface but decrease the content of hydrophobic groups, such as C—H and C—C groups [1–13]. The surface O/C atomic ratio has been found to be in good correlation with the mass loss of coal samples after oxidation processes [7,12]. C—O or C—O—C species have also been found to be oxidized to C═O and COO [2–5,12,14–16]. Meanwhile, the sulphur content usually has a significant effect on the oxidation processes of coal samples [7,8,13]. Coal rank also determines the oxidation processes or speed [12]. Low rank coals are easier to be oxidized than high rank coals, such as anthracite coal. The changes in organic materials on coal surface have been widely investigated during coal oxidation processes. However, the changes in inorganic materials on coal surface before and after natural weathering processes is usually ignored. Meanwhile, there only a few literatures about the changes in the surface topography of coal surface before and after natural weathering processes [17–19]. However, the surface topography of coal surface before and after pyrolysis processes [20–25]. It is necessary to take some studies on the surface topography of coal surface before and after natural weathering processes.

In this investigation, we attempted to find out both the changes in surface chemical properties and surface topography of coal surface before and after natural weathering processes. X-ray photoelectron spectroscopic (XPS) and scanning electron microscopy (SEM) were used to indicate these changes. Natural weathering processes of bituminous coal were conducted on the roof. The findings of this investigation are obtained by the combination of XPS and SEM results.

2. Experimental method and procedure

2.1. Materials and experiment design

Bituminous coal samples were obtained from Shanxi Province of China. Coal samples were dry-ground in a laboratory mill to pass 0.5 mm sieve. The proximate analysis of coal samples can be shown as follows: Mad = 3.00%, Vad = 16.52%, FCad = 58.17%, and

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Table 1
Contents of C1s, O1s, Si2p, and Al2p on bituminous coal surface before and after natural weathering processes.

Coal types	C1s (%)	O1s (%)	Si2p (%)	Al2p (%)
Fresh coal	63.86	24.30	6.66	5.18
After 3 months weathering	50.99	33.44	8.76	6.81
After 6 months weathering	37.65	42.81	11.05	8.49

Table 2
The fraction of C on bituminous coal surface before and after natural weathering processes (relative % of C1s).

Coal types	C—C, C—H (%)	C—O (%)	C=O (%)	O=C—O (%)
Fresh coal	55.31	38.74	5.95	0.00
After 3 months weathering	27.80	50.94	18.83	2.42
After 6 months weathering	8.79	50.99	31.45	8.77

Aad = 22.31%. Where Mad is the moisture content, Vad the volatile content, FCad the fixed carbon content, and Aad is the ash content on a dry basis.

Natural weathering processes of bituminous coal were conducted on the roof. The weathering times were three months and six months, respectively. Bituminous coal underwent the breakdowns from the sun, wind, and water. The oxidation processes occurred under natural environment.

2.2. XPS and SEM measurements

The XPS experiments were carried out at room temperature in an ultra high vacuum (UHV) system with the surface analysis system (ESCALAB 250Xi, America). The base pressure of the analysis chamber during the measurements was lower than

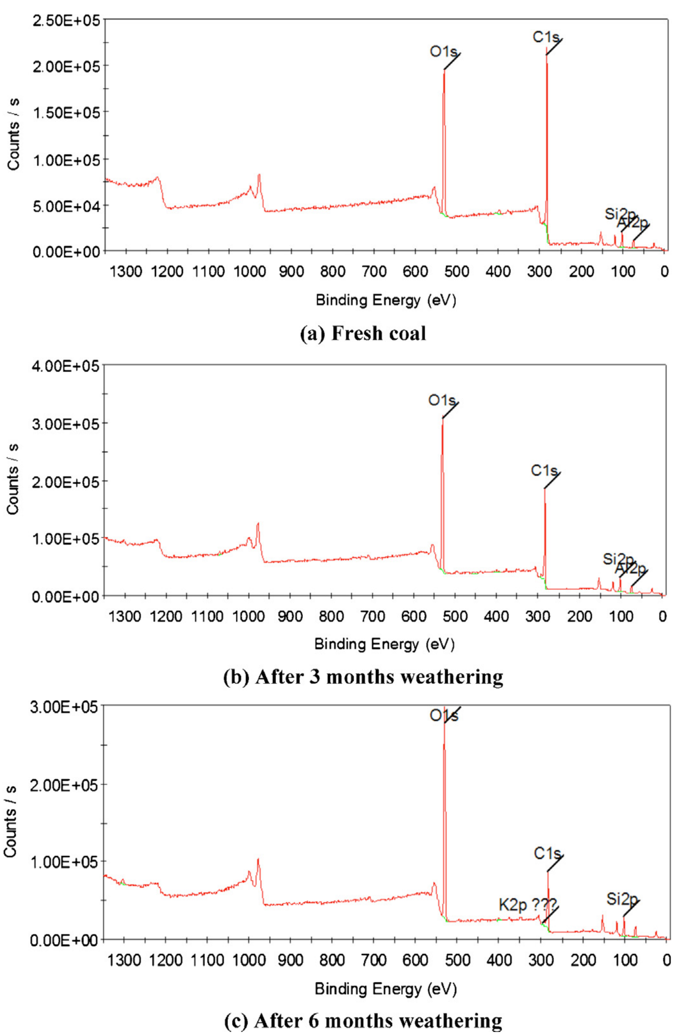

Fig. 1. XPS wide energy spectrum of bituminous coal surface before and after natural weathering processes.

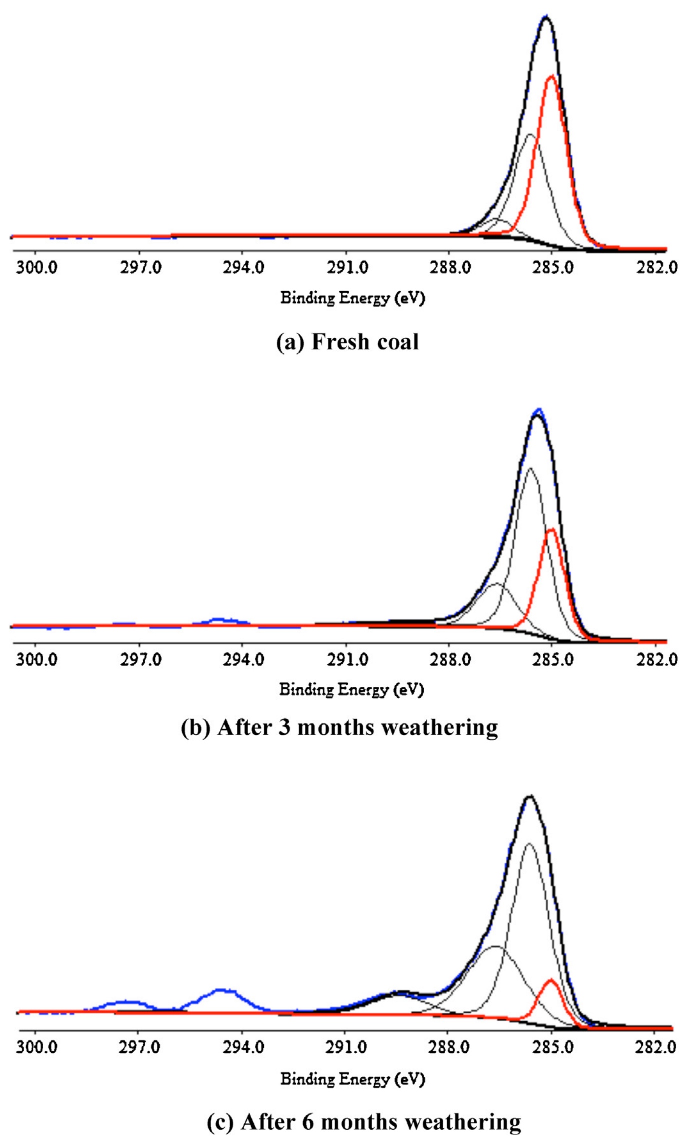

Fig. 2. C1s peaks for bituminous coal surface before and after natural weathering processes.